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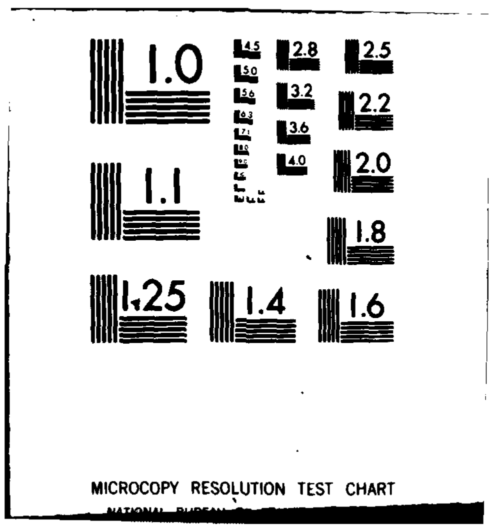
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A DISEQUILIBRIUM ADJUSTMENT MECHANISM FOR CPE MACROECONOMETRIC MODELS: INITIAL TESTING ON SOVMOD

Final

February 1979

Technical Note
SSC–TN–5943-6

By: Daniel L. Bond
Everett J. Rutan, III (WEFA)

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Prepared for:

Office of Economic Research
Central Intelligence Agency
Washington, D.C.

Contract 77N004691-000

SRI Project 5943

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Approved for Review Distribution:
Richard B. Foster, Director
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ABSTRACT

This report describes a disequilibrium adjustment mechanism for use in macroeconometric models of centrally planned economies. The mechanism is one that ensures that certain balances between supply and demand in specific sectors, or for specific factors, are adhered to in the model's solution. Given an initial set of endogenously determined variable values, the search for balance is designed to minimize the deviation from these inital values, while at the same time satisfying the balancing constraints.

Results of tests of the mechanism as introducted into the SRI-WEFA Soviet Econometric Model are also presented. These tests focused on reasonableness of the reaction of the model to the addition of the adjustment mechanism, changes in balances, and changes in error functions measuring deviations.

FOREWORD

This technical note represents research undertaken for the SSC's Soviet and Comparative Economics Program in the further development of the SRI-WEFA Econometric Model of the Soviet Union. The original Soviet Model Project was a three-year effort sponsored by the Defense Advanced Research Projects Agency, and was a cooperative research undertaking with the Wharton Econometric Forecasting Associates, Inc..

This report, authored by Daniel L. Bond (SRI International) and Everett J. Rutan, III (WEFA), describes work on the model aimed at facilitating the integration of a disequilibrium adjustment mechanism into the macroeconometric model. The author wish to acknowledge the substantial contribution that Dr. Per Strangert made to the development of the ideas presented in this paper. Also, the advise and assistance of Gary Fromm, Gene Guill, Edward Hewett, Holland Hunter, Lawrence Klein, and Herbert Levine are gratefully acknowledged.

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Senior Director
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I. INTRODUCTION

To the extent that a macroeconometric model simulates well over the historic period, it is likely that short-term forecasting with that model, under assumptions of limited deviation from past trends of the exogenous variables, will produce consistent results. However, no such confidence can be placed in projection results when an attempt is made to employ the same model for long-term forecasts, or when certain variables are assumed to take values substantially different from those observations upon which the model was estimated. In such cases it is likely that numerous inconsistencies will appear (or be implicit) in the numeric output of the model, inconsistencies which can either be ignored or corrected for by making parametric adjustments to some equations and resolving the model. This latter process is often a difficult and time consuming task, one which requires multiple simulations of the model coupled with extensive hand calculations by the user.

The purely operational disadvantages arising from the necessity of model adjustment should not, however, be overstated. Experience in forecasting with macroeconometric models has shown the inadequacy of a purely mechanistic approach to model use--one that assumes that after a model has been specified, the parameters estimated, and the system verified, that forecasting is a straightforward process of setting values for exogenous variables and solving the model. There are always biases and inadequacies in the model that preclude such practice. The need in forecasting for careful review and adjustment of model simulations cannot be eliminated--it is, in fact, a necessary and positive process.

Nevertheless, endogenous adjustment, leading to well defined balances, is clearly a desirable model property. It is toward this end that the research reported upon here has been directed.

In describing any economy at the macro level, there are numerous aspects of its structure which can be expressed in terms of identities. For example, the output of each sector of production is equal to the sum of intermediate and final consumption, net exports and changes in stocks of that output. Personal disposable income is equal to personal expenditures and savings. Other identity relationships can be defined for foreign trade, investment and labor allocations, national income aggregates, etc. If such balances are not insured by the internal structure of the model, and if in a particular scenario or forecast application adherence to these balances is necessary for proper analysis, the user is faced with the task of adjusting the model so as to obtain the necessary consistency. The difficulty is that there is usually an almost unlimited choice of adjustment routes.

In order to reduce the adjustment process to a manageable task, it is desirable that some mechanism be provided which aids the model user in obtaining consistency (in terms of the balances involved), and, even more importantly, which allows the model user to define an explicit and meaningful criterion of adjustment. If this can be done, the advantages it offers over ad hoc user adjustment are twofold. First, the adjustment criterion can be treated as a hypothesis, and ideally subjected to empirical testing. Second, by dealing with the problem in formal terms,

thus allowing inclusion of the adjustment process as part of the model solution algorithm, it becomes feasible to evaluate the interrelationships among adjustments when many balnces must be satisfied simultaneously.

In this paper we present our ideas on how an adjustment mechanism of the type described above may be formulated for inclusion in a macro-econometric model. This mechanism (a) insures that all well defined balances embedded in the model are satisfied, and (b) provides an explicit criterion of adjustment capable of relating all balancing adjustments in a meaningful manner.

Testing of this mechanism has been carried out using the latest version of the SRI-WEFA Soviet Econometric Model. This combines SOVMOD as described in Green, et al [1977] and the model of the energy sector of the Soviet economy developed by Bond [1978]. The system performed satisfactorily, and results of these tests are presented as illustrations of the flexibility of the operational form of the system.

We discuss in the next section the significance of the balancing mechanism for the task of modeling a centrally planned economy. We then present the mathematical derivation of the operational form of the adjustment mechanism. The theoretical implications for the behavior of the model are considered in detail. This is followed by a description of the implementation of the disequilibrium adjustment mechanism in SOVMOD: derivation of the balances, adjustment variables, objective functions. Finally, we report results of simulation experiments verifying the behavior of the model.

II. DISEQUILIBRIUM ADJUSTMENT IN A CENTRALLY PLANNED ECONOMY

Macroeconometric modeling of centrally planned economies (CPE) has only recently been attempted. Most CPE models developed to date have been patterned after approaches developed for market economy modeling, especially in the use of their supply side specifications. In a few cases, for example, in the SRI/WEFA Soviet Econometric Model (SOVMOD), an effort has been made to incorporate certain features reflecting the institutional structure of central planning, for example, in the use of plan data as anticipatory variables. However, there are two important aspects of modeling a CPE of the Soviet type for which we still lack an adequate methodological approach. These are:

(1) endogenizaton of the process by which plan targets are established; and

(2) determination of the causes and consequences of deviations from these targets.

For convenience, we will call the first of these the problem of guidance, and the second, the problem of adjustment.

We have not attempted, at this time, to investigate ways of modeling the process of plan formation, i.e., we have not addressed the problem of guidance. Only the second of these problems is considered here.

We feel that the modeling technique presented below will provide a means for gaining new insights into, and aid in the modeling of, the <u>adjustment</u> process. The basic assumption upon which we rest our hopes for this is that in a CPE's adjustment to imbalances during the process of plan fulfillment there is a consistent pattern of behavior incorporating a system of priorities among plan targets. If this assumption is valid, and if the system of priorities is relatively stable, we should be able, using the techniques here developed, to make explicit this behavior and use this information in modeling.

The approach taken here has much in common with certain ideas on non-price rationing as developed by Manove [1973]. Manove's concern was to devise a "...method for determining an optimal set of rationing priorities..." which could be used by an administrative bureaucracy for allocating intermediate goods for which unanticipated shortages have appeared. Such shortages may arise because of external shocks or internal production failures, or because of inconsistencies in the planned pattern of output.

In characterizing the type of economy in which non-price rationing is significant, Manove mentions the following: First "...production in these economies is frequently governed by inflexible short-term plans, which make it difficult to get around unforeseen shortages." Second, these economies "...normally operate with little slack...", yet they are modern industrial economies in which different sectors "...are highly dependent upon one another, directly and indirectly." Thus,

"...should production in one of these sectors falter, the performance of the entire economy could be threatened." Finally, lacking any well developed market mechanisms to respond to disequilibrium in supply and demand, there is a need for rather "...simple rules for distributing goods in short supply--rules that can be applied quickly by a decentralizd bureaucracy, whenever a shortage occurs."

This depiction of a CPE of the Soviet type appears to be widely accepted, and plays a central role in conceptual models of these economies. Yet, in most empirical CPE models no disequilibrium adjustment behavior is to be found, and the equality of supply and demand is attained, if at all, only by having a residual category in each balance. (Shapiro [1977]) In SOVMOD there are a number of specifications which reflect adjustment behavior. In equations containing variables for the harvest deviation, the ratio of actual to planned debt servicing, defense procurement expenditures, etc., there are estimated imbalance response coefficients. In these cases, however, the balances themselves are only implicit. This means that possible interaction in the response to multiple balancing constraints is not depicted in the model.

Since the initiation of the SOVMOD project there has been general agreement on the desirability of a more comprehensive treatment of this very important aspect of CPE modeling. It has been evident that part of the prerequisites for achieving this would be the introduction into the model of explicit balance equations, particularly balances of interindustry

supply. Substantial progress has been made in this direction, with the development of a time-series of balanced, constant price input-output tables now available for use with SOVMOD. What has been lacking to date is inclusion of a disequilibrium adjustment mechanism.

The two principal techniques of macro-modeling in which balance constraints play a significant role are (1) the traditional input-output model and (2) the more recently developed price responsive formulation of the input-output model. Neither was judged adequate to our task, the first because of limitations it places on the direction of causality (i.e., the necessity of determining one side of the demand-supply relationship as a requirement of the other); and the second because of the assumptions it makes as to short-term price-responsiveness and substitutability among inputs which is inappropriate for modling CPEs in which prices are set administratively and remain fixed for long periods of time.

Instead we have designed a mechanism by which imbalances are corrected by simultaneous adjustment in the levels of both supply and demand, with input coefficients (or other forms of parameters relating variables) remaining fixed in the short run. Such a system requires, as Manove points out, two sets of information. First, it is necessary to determine the impact that change at any point in the economy will have on all balances. This can be viewed as information on the structural characteristics of the economy. Second, it is necessary to know the

cost of any one adjustment relative to all other possible adjustments. For a CPE these costs are related to explicit or implicit expressions of planners' priorities. A possible adjustment mechanism is one that operates to satisfy all balance constraints while minimizing the total cost of adjustment.

In the approach we present below, we use what are essentially increasing functions of the absolute value of the deviation between the planned and realized (after adjustment) values of variables to represent the CPE planners' short-term priorities. These forms are subject to the following interpretation in terms of the real functioning of a CPE. It seems reasonable to expect that once the annual plan is established, all efforts will be directed at fulfillment of the plan targets as issued. If, during implementation, the initial plan cannot be met in all its aspects, it is unlikely that a new one can be recalculated in its entirety. In such a case, one strategy is to attempt to fulfill each target in the plan as closely as possible, with perhaps special emphasis placed on achieving key targets. A planners' response function in which "cost" increased with deviation above or below plan (though not necessarily symmetrically), would reflect this behavior. An important task for future research is to derive from a more rigorous theory of planners' behavior the form of objective function to use in guiding the adjustment process, and/or to empirically test competing forms.

At this state in our research, we simply take as given an initial model and append the adjustment mechanism to it. This allows us to test

the mechanical properties of our design. However, if we are to study the actual adjustment behavior of an economy, it is necessary that the initial model be specially designed to reflect the process of plan formation, as distinct from plan adjustment. Our feeling at this time is that planned levels of variables should be specified as functions of the differences between planned and realized values in previous periods, and various anticipatory variables. It is also possible that certain information resulting from the adjustment process itself (specifically the values of the Lagrangian multipliers discussed in the next section) can be used in simulating the guidance process. But a complete redesign of the initial model has yet to be carried out. Obviously, the modeling of guidance and adjustment must be undertaken simultaneously if we are to obtain analytically meaningful results.

III. DESIGN OF THE DISEQUILIBRIUM ADJUSTMENT MECHANISM

(a) We may depict the structure of our initial model (the model as specified without the disequilibrium adjustment mechanism) in the following way:

$$V = \Phi(V,E). \qquad (1)$$

Here, V represents the endogenous variables in the model and E the exogenous or predetermined variables. (In our notation, capital Latin letters represent vectors of variables and Greek letters to represent functions of these variables. Lower case, subscripted letters are used to represent individual variables and functions).

(b) Some balancing relationships among variables may already be observed in the initial model structure. However, it is likely that the remaining balances--those which we wish to observe through the adjustment process--are left undefined. These may be defined by an additional set of equations:

$$G = \Omega(V,E) \qquad (2)$$

(c) In the design of the adjustment mechanism, we are interested in modifying the structure of the initial model (1) so that in the solution process, we insure that $G = \emptyset$. One way this can be done is by selecting a set of adjustment variables from the set of endogenous variables, and adding equations to determine their adjusted values. Denoting the initial values (as determined by the initial model) as V^*, and the adjusted variables as V, we desire an augmented model:

$$V^{*} = \phi\,(V, E) \tag{3a}$$

$$V = \psi\,(V^{*}, E) \tag{3b}$$

$$G = \Omega\,(V^{*}, E) = \emptyset \tag{3c}$$

where the equations (3b) determine adjusted values of the endogenous variables. These adjusted values guarantee that the balances in (2) are zero. Our task is to design a mechanism for obtaining a set of equations ψ which will yield the adjusted values as part of the model solution process.

(d) We take as our criterion of adjustment a cost function which is increasing in the deviation of adjusted form initial values for each of the endogenous variables which we allow to adjust. The problem is formalized as follows:

$$\text{minimize} \quad \theta\,(V-V^{*}) = \sum_{i=1}^{m} \sigma_i\,(v_i - v_i^{*}) \tag{4}$$

such that $g_k = \Omega_k\,(V, E) = \emptyset$

for $k = 1,\ldots, n$ (5)

(e) The solution to the adjustment problem is found in the standard fashion. Forming the Lagrangian function, Z, from (4) and (5):

$$Z = \sum_{i=1}^{m} \sigma_i\,(v_i - v_i^{*}) + \sum_{k=1}^{n} \lambda_k\, g_k \tag{6}$$

Derivatives with respect to v_i and λ_k determine the necessary conditions for an optimum:

$$\frac{\partial Z}{\partial v_i} = \frac{\partial \sigma_i (v_i - v_i^*)}{\partial v_i} + \sum_{k=1}^{n} \lambda_k \frac{\partial g_k}{\partial v_i} = 0$$

for $i = 1,\ldots,m$ (7)

$$\frac{\partial Z}{\partial \lambda_k} = g_1 = 0 \qquad \text{for } k = 1,\ldots,n \qquad (8)$$

(f) In (7) and (8) we have m + n equations to determine the value of the m + n variables v_i, $i = 1,\ldots,m$ and λ_k, $k = 1,\ldots,n$. Taking our cue from (3) above, we donote these as:

$$\Psi (V, V^*, L, E) = 0 \qquad (9a)$$

$$G = \Omega (V, E) = 0 \qquad (9b)$$

With (3a), which we repeat here:

$$V^* = \Phi (V, E) \qquad (9c)$$

the system is complete.

(g) While the system is complete in the sense that the number of equations and unknowns are equal, that is no guarantee that the system can be solved. And even if the system of equations (9) has a solution, the first order conditions are merely necessary for, not sufficient to guarantee that the objective function has been minimized.

The existence of a solution will depend on the functions Ω_k and σ_i. If these are fairly well behaved, a solution will be possible. Specifically, we would like the system of balances (2b) to be independent. As the Langrangian multipliers appear only in the adjustment equations (7) or (9a), there must be at least as many adjustment variables as balance constraints. (This is the mathematical counterpart of the notion that we must have as many controls as items to control.) Each of the σ_i should reach a minimum at 0 and be strictly increasing in either direction away from zero.

Given that we can solve (9), that we have also minimized the objective function is still not certain. The form of the cost functions, σ_i, and the fact that the solution algorithm will start out with $V = V^*$ are intuitively appealing but not mathematically demonstrative. While it is theoretically possible to evaluate the sufficient conditions for minimization, the disucussion below of determining $\partial g_k/\partial v_i$ demonstrates this is impractical.

We know from the theory of Lagrangian multipliers that:

$$\lambda_k = \frac{\partial \theta (V-V^*)}{\partial g_k} \tag{10a}$$

or for small changes:

$$\lambda_k = \frac{\Delta \theta (V - V^*)}{\Delta g_k} \tag{10b}$$

This provides another check on our solution.

(h) The cost functions, σ_i, will reflect our assumptions as to planners' behavior. The general assumption that σ_i is a function of $v_i - v_i^*$ and is increasing as we move away from zero reflects a belief that any deviation from initial or plan value is undesirable, due to the interdependencies among sectors of the economy. However, the exact form of σ_i will be the subject of much future theoretical and empirical work, and is not taken up in this report.

For testing purposes, several particular forms of σ_i suggest themselves. Perhaps the simplest is to consider the weighted absolute or proportional deviation:

$$\sigma_i = \frac{1}{a_i} | v_i - v_i^* | \tag{11}$$

$$s_i = \frac{1}{a_i} \frac{| v_i - v_i^* |}{v_i^*} \tag{11'}$$

For example, use of (11a) will yield adjustment equations (7) of the form:

$$\emptyset = \pm \frac{1}{a_i} + \sum_{k=1}^{n} \lambda_k \frac{\partial g_k}{\partial v_i} \text{ as } v_i \gtrless v_i^* \qquad (12)$$

The dependence of the form of the equation on the relative values of v_i and v_i^* does not make either (11a) or 11b) easily usable.

The 'traditional' cost function is the weighted quadratic:

$$\sigma_i (v_i - v_i^*) = \frac{1}{a_i} \cdot \frac{1}{2} (v_i - v_i^*)^2 \qquad (13)$$

which yields:

$$\emptyset = \frac{(v_i - v_i^*)}{a_i} + \sum_{k=1} \lambda_k \frac{\partial g_k}{\partial g_i} \qquad (14)$$

The advantages of this form are first theoretical, in that cost increases exponentially with size of deviation, and practical in that (14) is linear in v_i and λ_k. A minor modification converts this into proportional deviation form:

$$\sigma_i (v_i - v_i^*) = \frac{1}{a_i} \cdot \frac{1}{2} \left(\frac{v_i - v_i^*}{v_i^*}\right)^2 \qquad (13')$$

$$0 = \frac{(v_i - v_i^*)}{a_i \cdot (v_i^*)^2} + \sum_{k=1}^{n} \lambda_k \frac{\partial g_k}{\partial v_i} \qquad (14')$$

The forms discussed so far have the disadvantage of being symmetric in respect to positive and negative deviations. In fact, the cost of missing the plan or initial value may be far different depending on the sign of the error. For several reasons, failing to meet a target may be far more costly than exceeding it. Alternately, if the initial value represents a physical maximum, exceeding it may not be possible.

In terms of asymmetry, the following cost function is quite handy:

$$\sigma_i (v_i - v_i^*) = \frac{1}{a_i} \cdot \frac{1}{2} \left(\frac{v_i - v_i^*}{b_i \ v_i^* + (1 - b_i) \ v_i}\right)^2 \qquad (15)$$

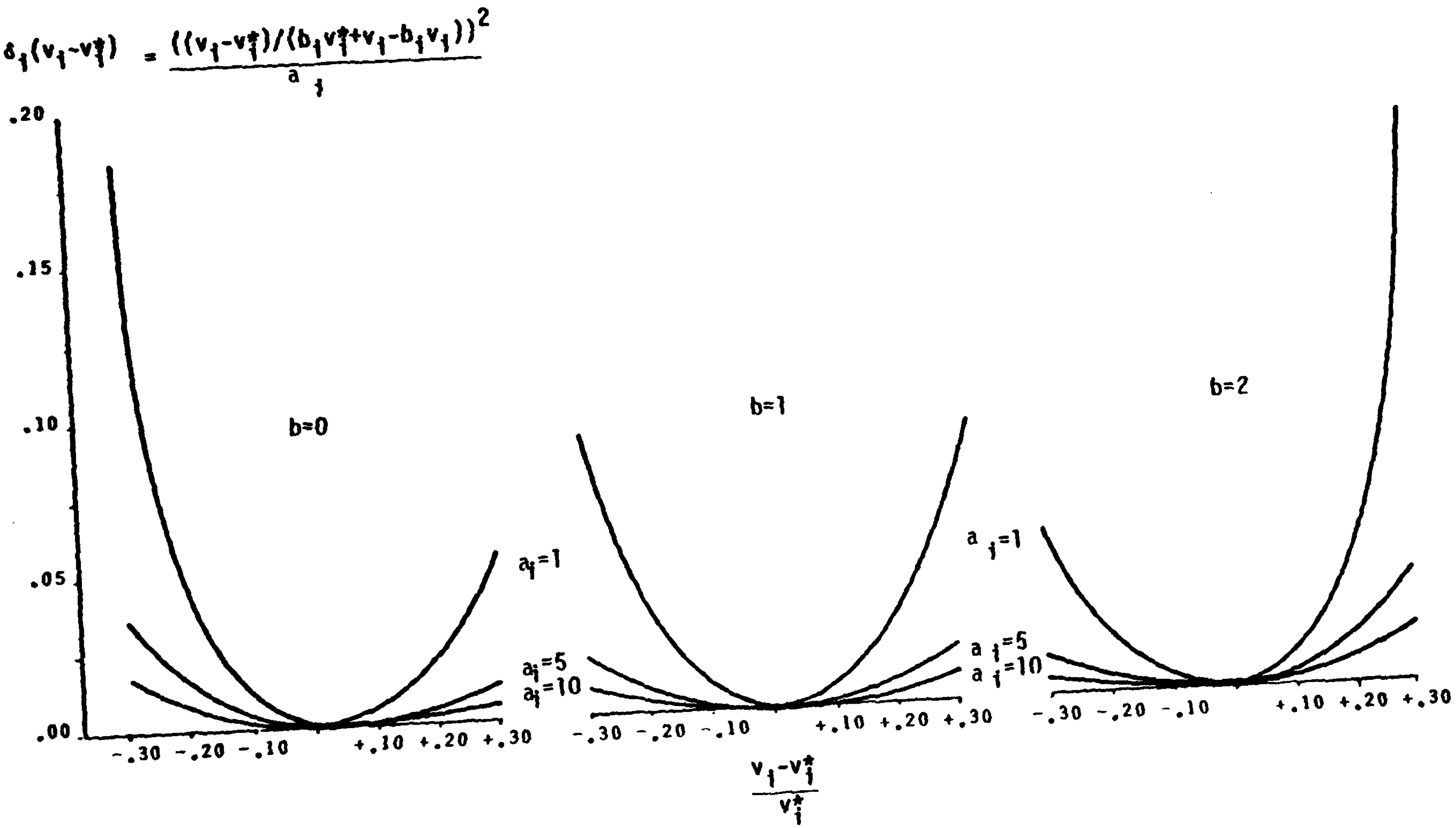
which yields the adjustment equation:

$$0 = \frac{(v_i - v_i^*) \ v_i^*}{a_i \ (b_i \ v_i + (1 - b_i) \ v_i^*)^3} + \sum_{k=1}^{n} \lambda_k \frac{\partial g_k}{\partial v_i} \qquad (16)$$

As demonstrated in figure 1, for $b_i = 1$, we have the case of symmetric, weighted, squared proportional deviation. For $b_i < 1$ shortfall is more expensive than excess, and for $b_i > 1$ exceeding plan is more expensive than falling short.

Figure 1

ILLUSTRATIVE FORMS OF COST FUNCTIONS



In terms of physical limitation, the most useful form of a cost function is one that becomes infinitely large as the boundary is approached. The asymetric cost function is also handy in this regard. Note that the cost becomes infinite as v_i approaches:

$$\frac{-v_i^* \cdot b_i}{(1 - b_i)} \tag{17}$$

By altering the value of b_i, the point of intinite cost can be brought in as close as we please to v_i^*.

The cost function (14) is a special case of (15) for which $b_i = 1$. Hence (15) is a very flexible specification. Also, the derivative of this cost function is always zero for $v_i = v_i^*$. As it is the derivative of the cost function which appears in the adjustment equation (7), it is possible to choose different cost functions with different parameters for positive and negative deviations. The smoothness of these functions at $v_i = v_i^*$ assures the model will be stable.

(i) Equations (7) or (9a) require that we be able to evaluate $\partial g_k/\partial v_i$ for all k and i. If each balance were a straightforward function of the adjustment variables, and the cross derivatives between endogenous variables were zero, we would be able to obtain these synthetically. However, the balances may be in terms of endogenous variables not specifically chosen for adjustment, and as we are dealing with the simultaneous system (9), cross derivatives are significant.

We propose two methods of approximation. First, where the equations are straightforward, the synthetically determined derivative will be very close to the true value. e.g.:

$$g_k = w_k \ (v_i, v_j, v_l)$$

$$v_l = \phi_l \ (v_i, E) \qquad (18)$$

$$\partial g_k / \partial v_i \simeq \frac{\partial_{wk}}{\partial v_i} + \frac{\partial_{wk}}{\partial v_l} \frac{\partial \phi_l}{\partial v_i}$$

Second, for small changes:

$$\frac{\partial g_k}{\partial v_i} \simeq \frac{\Delta g_k}{\Delta v_i} \qquad (19)$$

By simulating the model without the complete balancing mechanism but with the balance equations in place:

$$V = \phi \ (V, E)$$

$$G = \Omega \ (V, E) \qquad (20)$$

we obtain values of the imbalances in the initial model solution . We may then exogenize each of the v_i in turn, and re-solve the model using $v_i + \Delta v_i$ to determine ΔG. The ratios give approximations to the derivatives.

(j) It should be noted that the method described here is not an optimal control technique. The disequilibrium adjustment mechanism we have described is simply a way of allocating throughout the model the single period changes needed to accommodate specific, economically indicated balances or constraints. No explicit attempt is made to optimize activity over time.

IV. IMPLEMENTATION OF THE DISEQUILIBRIUM ADJUSTMENT MECHANISM IN SOVMOD.

The mechanism we have described above is very general in that it can be used to implement any constraint, using any set of endogenous variables for adjustment. The choice of constraints and adjustment variables will depend on the purpose and intuition of the economist, as well as the availability of data. For the purpose of testing the disequilibrium adjustment mechanism in SOVMOD we chose to implement supply-demand equality constraints on production drawing on recent work on Soviet input-output coefficients (Guill [1978], Bond and Rutan [1978]) and energy supply and demand (Bond [1978]).

SOVMOD, like most macro-econometric models which are disaggregated by industry, has capital-labor production functions which predict the level of output from factor availability. Because of the nature of the Soviet economy, this supply is not balanced against demand through a model of the market. Prices in the Soviet Union are centrally determined and are not market clearing prices.

The availability of input-output tables, or, in the case of energy, material balances, yields an alternative means of determining the supply and demand balance: determination by category of use. The presence of balance or imbalance is given by subtracting intermediate uses, exports and final demand, from the sum of production and imports. The obvious choice of adjustment variables is the output of the industries involved, which should be allowed to vary until supply and demand are equal. Embedding this process in the full econometric model assures all of the secondary changes necessary for consistency are carried out.

In the absence of a specific model of planners' behavior, we feel the adjustment-minimization approach of our mechanism is a reasonable first approximation. The GOSPLAN attempts to set targets and incentives which result in a balanced system of product and uses. As inconsistencies develop--material shortages, oversupplies, etc.--managers attempt to stay near the target and incentives. Ad hoc priorities are followed. Of course, the exact form of error functions and weights which will form a good approximation to this complex activity and which, in the context of SOVMOD, will lead to good simulation results, are a subject for further study and experimentation and we do not attempt that now. However, demonstrating that some such functions and weights will lead to a working model is a necessary first step, and this is done here.

Table I lists the industrial sectors for which we impose supply-demand constraints, and how they are balanced (either in value terms, through the input-output table relations, or in material terms). Table II lists the sector outputs which are allowed to adjust, and the units of measurement. Conversions between index, value and material units are done through linking equations in the model. To indicate plan or initial variables, we prefix 'P.' to the variable name.

In the non-energy sectors, initial or plan levels of output are determined by the capital-labor production functions:

$$P.X_i = f(K_i, N_i) \tag{21}$$

TABLE I
BALANCED SECTORS

SECTOR	VARIABLE	SOURCE	UNITS
Metallurgy	XIOME	IO Tables	1970 Rubles
Coal	XTCOP	Energy Model	Tons
Oil	XTOIP	Energy Model	Tons
Gas	XTGAN	Energy Model	Cubic Meters
MBMW	XIOMB	IO Tables	1970 Rubles
Chemicals	XIOCH	IO Tables	1970 Rubles
Wood	XIOFP	IO Tables	1970 Rubles
Paper	XIOPA	IO Tables	1970 Rubles
Construction Materials	XIOCM	IO Tables	1970 Rubles
Soft Goods	XIOSG	IO Tables	1970 Rubles
Processed Foods	XIOPF	IO Tables	1970 Rubles
Construction	XIOCN	IO Tables	1970 Rubles
Agriculture (Output Actual)	XIOAG	IO Tables	1970 Rubles

TABLE II
ADJUSTED SECTORS

SECTOR	VARIABLE	SOURCE	UNITS
Ferrour Metallurgy	XOFM	SOVMOD	Index, 1970=100
Non-ferrous Metallurgy	XONF	SOVMOD	Index, 1970=100
Coal	XOCP	SOVMOD	Index, 1970=100
Oil	XTOIP	Energy Model	Tons
Gas	XTGAN	Energy Model	Cubic Meters
MBMW	XOMB	SOVMOD	Index, 1970=100
Chemicals	XOCH	SOVMOD	Index, 1970=100
Wood	XOFP	SOVMOD	Index, 1970=100
Paper	XOPA	SOVMOD	Index, 1970=100
Construction Materials	XOCM	SOVMOD	Index, 1970=100
Soft goods	XOSG	SOVMOD	Index, 1970=100
Processed Foods	XOPF	SOVMOD	Index, 1970=100
Construction	XOCN	SOVMOD	Index, 1970=100
Agriculture (Potential Output)	XAGTN	SOVMOD	1970 Rubles

For reference purposes, we then calculate the initial imbalances:

$$P.G_i = P.XIO_i + I_i - E_i - \sum_{j=1}^{18} A_{ij} \; P.XIO_j \qquad (22)$$

where I_i are imports, E_i exports and A_{ij} the coefficient for deliveries from industry i to industry j. Hence the last term equals inter-industry use of sector i outputs.

The initial or plan output of the energy sectors are determined in material terms from industry specific considerations of reserves, past drilling and transportation capacity. Note that the electric power sector is balanced within the energy sector itself. Only coal, oil and gas enter into the dynamic adjustment mechanism.

For all sectors to be adjusted, we enter the balance constraints:

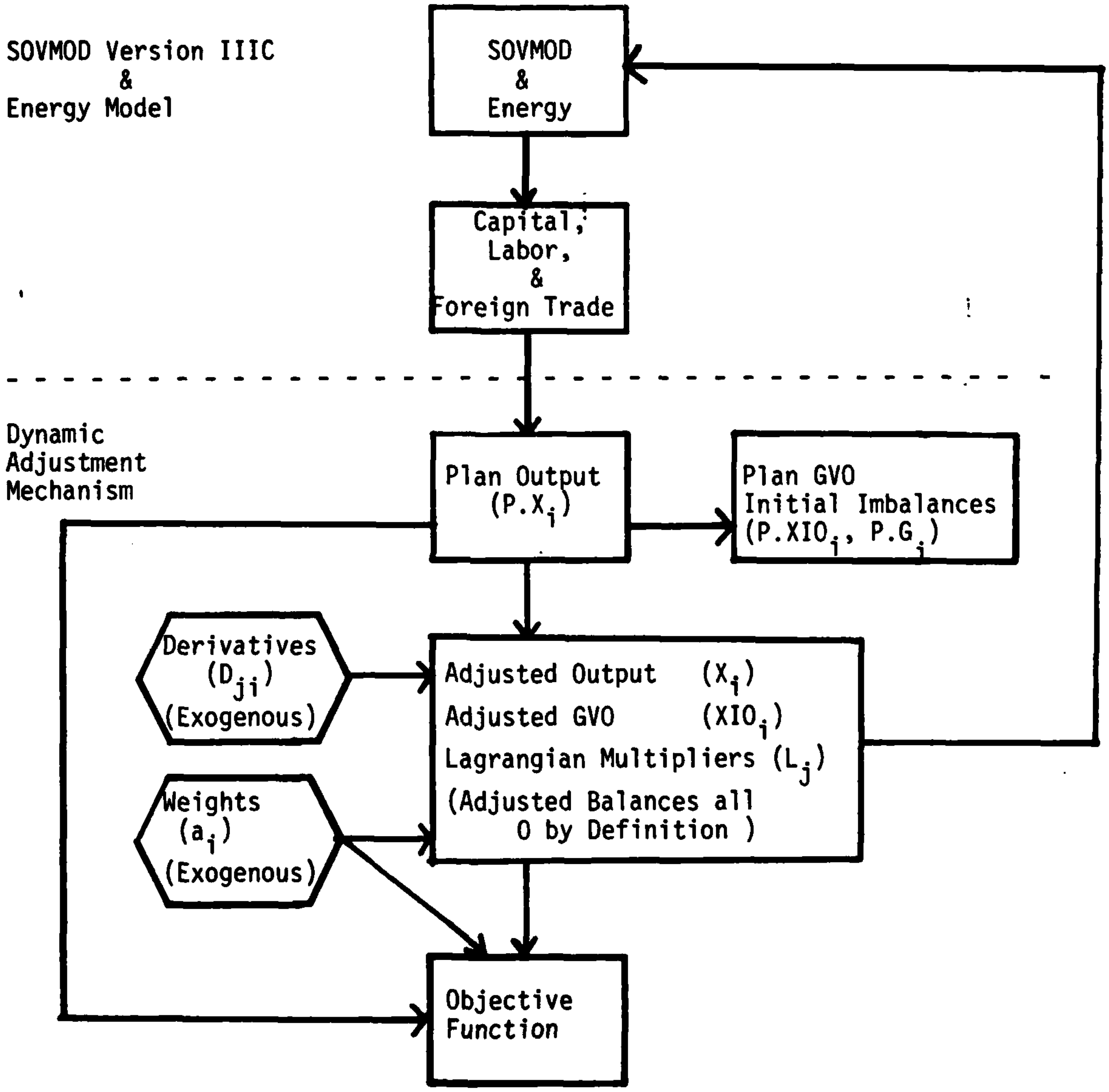
$$G_i = 0 = XIO_i + I_i - E_i - \sum_{j=1}^{18} A_{ij} \; XIO_j \qquad (23a)$$

for sectors balanced through the input-output system, and

$$G_{i'} = 0 = X_i + I_i - E_i - U_i \qquad (23b)$$

for coal, oil and gas, where U_i indicates domestic uses.

Figure II



Because capital, labor and foreign trade feed into the adjustment mechanism and are to some extent affected by adjusted output, the entire svstem forms one larae simultaneous block.

Adjustment equations are entered for each sector allowed to adjust:

$$\emptyset = \frac{\partial\, \sigma_i\, (X_i - P.X_i)}{\partial X_i} + \sum_{j=1}^{13} L_j \frac{\partial Gj}{\partial X_i} \qquad (24)$$

where σ_i is the adjustment-cost function for sector i, L_j the Lagrangian multipliers or shadow prices of adjustment, and G_j corresponds to a constraint of type (23a) or (23b) in functional form. Derivatives are calculated synthetically for all but the three energy sectors, whose derivatives are estimated as discussed above.

Finally, and again for reference, the objective function is included in the model:

$$\text{Deviation} = \sum_{j=1}^{14} \sigma_i \; (X_i - P.X_i) \qquad (25)$$

In terms of the theoretical framework discussed in Section III above, SOVMOD plus equations (22) correspond to (9c), equations (23) to (9b) and equations (24) to (9a).

A clearer indication of the structure introduced into the model solution is given in Figure II. In the main causal flow factor supplies drive production function estimates of plan or initial levels of output. These are introduced into the adjustment mechanism which determines output levels which meet the supply-demand constraints, and shadow prices

of the constraints in terms of the objective functions. The adjusted values of output are then used to drive SOVMOD. Because current output affects factor supplies--predominately the effect of agricultural output on labor supply--the system feeds back into itself. Additional feedback occurs through the foreign trade sectors and the energy sector. However, as will be seen below, this feedback is not very strong.

It should be noted that causality in the model is an economic mode of thought. Full simulation solves the equations of the model simultaneously, and the mathematical effect of the adjustment mechanism is to increase the degree of simultaneity, or interconnectedness in the system. This is the expected effect of constraining the model.

Except for the question of units of measure, the balancing of most sectors is straightforward. However, agriculture presents particular problems in that actual output is greatly affected by the weather, which is not a controllable variable, at least not yet. Our decision has been to balance the agricultural sector in terms of actual output, as this is compatible with the available input-output system data, and would seem to represent the claims on agriculture by the rest of the economy and vice versa. Adjustment in the agricultural sector is done in terms of potential agricultural output, which responds to controllable factors.

V. TEST RESULTS

The purpose of this section is to report the results of various tests which indicate that the disequilibrium adjustment mechanism behaves in SOVMOD as one would expect. As there are over 400 variables determined endogenously in SOVMOD, and as these are preliminary results, the only data presented here is that minimum necessary to illustrate the point at hand. Throughout the testing we have used a cost function of the type (15), and unless otherwise specified, all a_i and b_i parameters were set equal to one.

(a) Solvability. The model does solve with the disequilibrium adjustment mechanism. Table III indicates GNP, imbalance at planned levels for the metallurgy sector, and actual output of the ferrous metallurgy sector for solutions with and without the adjustment mechanisms. Because most of the imbalances at initial levels of output are positive, indicating excess supply or insufficient demand, the overall effect of the adjustment process is to reduce output, hence GNP. This is not an indication of oversupply potential in the Soviet economy, but rather a reflection on our balance equations at the current time.

Note that while constraining the model reduces GNP, it does not mean that some sector outputs cannot actually increase over planned levels, or vary from year to year. Note also that the imbalances at planned levels of output are very close for both models. This indicates that the feedback from the adjusted values of output into labor and capital, and from these into the planned values of output, is not a significant problem.

TABLE III
P.B.01

Year	GNP (B1970R) (1)	GNP (B1970R) (2)	IMBALANCE METALLURGY (B1970R) (1)	IMBALANCE METALLURGY (B1970R) (2)	OUTPUT FERROUS METALS (Index) (1)	OUTPUT FERROUS METALS (Index) (2)
1968	334	304	1.22	1.14	93	82
1969	352	323	1.47	1.41	98	87
1970	374	349	1.31	1.18	102	94
1971	390	368	.85	.67	106	100
1972	400	371	-.33	-.52	109	103
1973	427	404	-.94	-1.10	112	111
1974	446	420	-1.70	-1.97	116	116
1975	450	420	-3.50	-3.76	120	126

(1) Model solution, no adjustment

(2) Model solution, dynamic adjustment mechanism

TABLE IV

ADJUSTED OUTPUT AS % OF PLANNED OUTPUT

	(i) CHEMICALS		(ii) FERROUS METALS		NON-FERROUS METALS	
	a=1	a=.5	a=1	a=2	a=1	a=.5
1968	53	61	89	81	86	93
1969	63	63	89	81	86	94
1970	65	65	93	87	90	96
1971	69	69	95	92	93	97
1972	68	68	95	91	92	96
1973	71	71	100	99	98	99
1974	68	68	101	101	98	99
1975	64	64	106	109	104	101

There are two important facts about the model solution process which should be noted. First, there is an enormous increase in simultaneity, and therefore in cost and sensitivity. Without the disequilibrium adjustment mechanism, 58% of all endogenous variables are determined in the largest simultaneous block. With adjustment, the proportion rises to 70%.

Second, econometric models are usually set up so each equation is specifically estimated for and used to determine a particular endogenous variable. This is not true with the disequilibrium adjustment mechanism in place. For example, which of the adjustment equations of type (24) should be solved for each Lagrangian multiplier? This is further complicated by the fact that the model has 13 sectoral balances but 14 output variables for adjustment. As a result, model solution is, to a degree arbitrary, as it depends on how equations are treated by the solution algorithm.

(b) Sector Weights. We would expect that as the weight factor, a_i, on a sector cost function increases the cost of adjustment of that sector, then the adjusted value of output will be closer to the planned value. Table IV (i) represents the result of doubling the cost of adjustment in the chemicals industry. Note that while the adjusted output as percentage of plan never gets worse, it does not improve significantly.

Compare this to Table IV (ii) where the cost of adjustment in ferrous metallurgy has been halved, and that in non-ferrous metallurgy doubled. Both of these variables directly affect the balance of the metallurgy sector. As indicated, there is a clear shift in adjustment to the less costly sector, ferrous metallurgy.

When we look to Table V, the total adjustment cost for each of these tests, it becomes clear that the disequilibrium adjustment mechanism is reluctant to shift adjustment across sectors. When adjustment in the chemical sector is costly, total adjustment costs rise, rather than adjustment being shifted to other branches of the economy. By contrast, in the case of metallurgy, the presence of two control variables allows cost to be shifted <u>within</u> the branch so as to prevent total cost of adjustment from increasing at all. While it is intuitively obvious that the system would use the most effective variable to balance each sector, this failure to shift across sectors requires further investigation.

(c) Bounding. Changing the b_i parameter in the cost function should allow setting of upper or lower bounds at which the cost of adjustment increases to infinity. Table VI shows two experiments, one in which an upper bound of 110% of planned output was set for the construction industry (VI, i) and one in which a lower bound of 75% of plan was set for chemicals (VI, ii). Neither bound was effective, though the total cost of adjustment clearly increased sharply as the bound was approached. The explanation for this is that the cost function is well-defined on both sides of the point at which cost becomes infinite. As model solution

TABLE V

TOTAL COST OF ADJUSTMENT

YEAR	BASE CASE (all a=1)	(i) CHEMICALS (a=.5)	(ii) METALLURGY (Ferrous a=2, Non-ferrous a=.5)
1968	.31	.39	.31
1969	.25	.32	.25
1970	.20	.26	.20
1971	.14	.19	.14
1972	.18	.23	.18
1973	.14	.18	.13
1974	.17	.22	.17
1975	.22	.29	.22

TABLE VI

BOUNDED ADJUSTMENT

	CONSTRUCTION UPPER BOUND 110% OF PLAN		CHEMICALS LOWER BOUND 75% OF PLAN	
YEAR	OUTPUT AS % OF PLAN	TOTAL COST	OUTPUT AS % OF PLAN	TOTAL COST
1968	104	.31	61	.47
1969	100	.24	63	.49
1970	111	1.52	65	.54
1971	108	1.23	68	.82
1972	109.5	2.92	68	.81
1973	113	.20	71	1.52
1974	114	.22	68	.72
1975	117	.24	64	.52

is by a discrete, iterative procedure, the adjusted output values may "tunnel" under this point of greatest cost. Much greater care will have to be taken in implementation to make this bounding cost function workable.

(d) Shadow Prices. Theory tells us that the Langrangian multiplier is the rate of change of the objective function with respect to a constraint. For small discrete changes, the relationship given in equation (10b) should hold. Table VII lists the results of an experiment in which the chemical industry constraint was relaxed by 5 billion rubles, or about half the imbalance at planned output levels. Note that the shadow price multiplied by the change in the constraint is clearly of the same order of magnitude as the change in the objective function, whether the shadow price used is that computed before or after relaxation. This is an encouraging result, in that it suggests we are achieving minimization of the cost of adjustment in the model.

TABLE VII

SHADOW PRICES AND CHANGING COST

CHEMICAL INDUSTRY
(all values x 10**-3)

YEAR	LAGRANGIAN X CHANGES IN CONSTRAINT Constrained	Relaxed	CHANGE IN TOTAL COST
1968	.36.5	25.4	66.6
1969	.30.5	20.9	50.9
1970	.23.9	15.5	34.3
1971	.18.5	11.2	22.2
1972	.24.5	18.0	30.2
1973	.15.8	10.4	16.9
1974	.16.6	11.7	17.3
1975	.14.5	10.6	18.7

VI. FUTURE TASKS

As the preceding section showed, much more testing needs to be done on the simple mechanical properties of the disequilibrium adjustment mechanism as applied to SOVMOD. The sensitivity of the model to its many new parameters should be explored until a more intuitive understanding of cause and effect is developed.

Beyond this, however, are a number of important econometric tasks which must be undertaken in order to bring the model up to the level required for a baseline forecast and scenario analysis. These are:

(1) The "planned" values of output are determined from capital-labor production functions, the inputs of which are ultimately affected by the adjustment mechanism. This may not be a correct, or even a good specification. Ultimately, this leads into the problem of plan formation.

(2) The equations which link the index and physical unit measures of output with the input-output system gross values of output simply do not predict as well as could be expected. In part, this is because the index-varaiables measure net output, and the other variables measure gross output. These relations need to be corrected.

(3) The final demand sector of product use needs to be properly calculated in order for the balances to be properly specified. Currently only a rough estimate is used, and, as a result, excess supply is indicated in most sectors.

(4) The agricultural sector is balanced in terms of actual output, while the variable used to adjust this sector is the SOVMOD "normal" agricultural output variable. The difference between the two is the largely random effects of weather. While this seemed to be the rational way to apply balancing to agriculture, its implications need to be studied further.

(5) The dynamic adjustment mechanism postulates a cost of adjustment and priority for each sector which is to be balanced. These must be determined and verified with respect to the Soviet economy.

Only when this basic work is done will it be possible to attempt baseline forcast and scenario analysis with the adjusted version of SOVMOD. In the longer run, a version of SOVMOD should be developed in which balances are central to the model's structure, rather than added on.

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